CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
DEPARTMENT OF TOXIC SUBSTANCES CONTROL
Final Decision to Certify
Hazardous Waste Environmental Technologies

The California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) intends to certify the following company's hazardous waste environmental technology:

Applicant: ABB, Inc.
2135 Philpott Road
South Boston, Virginia 24592

Technology: BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid

Chapter 412, Statutes of 1993, Section 25200.1.5, Health and Safety Code, enacted by Assembly Bill 2060 (AB 2060 by Assemblyman Ted Weggeland) authorizes DTSC to certify the performance of hazardous waste environmental technologies. The purpose of the certification program is to provide an in-depth, independent review of technologies at the manufacturers' level to facilitate regulatory and end-user acceptance. Only technologies that are determined to not pose a significant potential hazard to the public health and safety or to the environment when used under specified operating conditions may be certified. Incineration technologies are explicitly excluded from the certification program.

DTSC makes no express or implied warranties as to the performance of the manufacturer's product or equipment. The end-user is solely responsible for complying with the applicable federal, state, and local regulatory requirements. Certification does not limit DTSC's authority to require additional measures for protection of public health and the environment.

By accepting certification, the manufacturer assumes, for the duration of certification, responsibility for maintaining the quality of the manufactured equipment and materials at a level equal to or better than was provided to obtain certification and agrees to be subject to quality monitoring by DTSC as required by the statute under which certification is granted.

DTSC's proposed decision to certify was published on January 18, 2002 in the California Regulatory Notice Register 2002, Volume No. 3-Z, pp.218-227 and was subject to a 30-day public review and comment period. Written comments were submitted to DTSC. All comments received were considered and appropriate changes were made prior to publishing this final decision. The main comment submitted by the vendor and other interested parties was that the aquatic toxicity tests performed by California EPA were not analyzed in accordance with the method established in California regulations and misrepresented the product’s aquatic toxicity effect. The LC_{50} values obtained using this methodology were below the 96-hour fish bioassay toxicity value of 500 milligrams per liter (mg/L) listed in the California hazardous waste regulations. The vendor’s comment are available in Section 7.0 of the June 2002 Final U.S. EPA Environmental Technology Verification Report. Although the Department appreciates and understands the vendor’s concerns, the Department has determined the aquatic toxicity tests were conducted per the requirements outlined in the California hazardous waste regulations for toxicity. DTSC’s Final Certification shall become effective on August 11, 2002.

Additional information supporting DTSC's final decision is included in the June 2002 Final U.S. EPA Environmental Technology Verification Report, and is available for review. Requests for additional information concerning the final decision should be submitted to the following address:

California Environmental Protection Agency
Department of Toxic Substances Control
Office of Pollution Prevention and Technology Development
P.O. Box 806
1001 I Street, 12th Floor
Sacramento, California 95812-0806
Attn: Suzanne Davis (916) 327-4206
http://www.dtsc.ca.gov/sciencetechnology/TechCert_index.html

A description of the technology to be certified, the certification statement and the certification conditions and limitations for the technology of the company listed above follow.

CERTIFICATION PROGRAM (AB 2060) FOR
HAZARDOUS WASTE ENVIRONMENTAL
TECHNOLOGIES

FINAL NOTICE OF TECHNOLOGY CERTIFICATION
BIOTEMP® VEGETABLE OIL-BASED INSULATING DIELECTRIC FLUID

Technology: BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid

Manufacturer: ABB, Inc.
2135 Philpott Road
South Boston, Virginia 24592

Technology Description

The BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid (BIOTEMP®), developed by ABB Inc. (ABB), is a vegetable oil-based dielectric fluid comprised of greater than 98.5% vegetable oil and less than 1.5% antioxidants. The product may use up to three different antioxidants to prevent unsaturated bonds in the oil from polymerizing with oxygen. The vegetable oil used in BIOTEMP® is manufactured off-site in a four-step process: crushing and refining, bleaching, deodorizing, and winterizing. The oil is extracted from crushed seeds using a solvent such as hexane. As part of the bleaching process, the oil is subject to a clay treatment to remove polar contaminants. Next, the oil is deodorized using steam distillation to remove unwanted volatile compounds. The last step, winterizing, involves chilling the oil to remove excessive saturates. The vegetable oil is then blended with the antioxidants per ABB's product specifications. ABB is currently using blending equipment at their South Boston, Virginia facility to oversee and control this portion of the process.

BIOTEMP® is used in liquid-filled electrical transformers as an electrical insulating medium. The main parts of a transformer are the core, the windings, the tank containing the core and windings, and the cooling system. The core is made of thin steel sheet laminates, which are coated with an oxide film to insulate the sheets from each other. Two distinct sets of coils called windings are placed upon the core at a suitable distance from each other. These windings consist of wire insulated with a paper covering. When the transformer is in-service, the oil and core expands and contracts as the heat generated by the transformer windings varies with the load. As the oil becomes heated, the hot oil rises to the top of the transformer where heat is dissipated to the outside, and then moves along the case to the bottom. Fins are sometimes attached to deflect moving air against the case and to increase the cooling area. Overheating the core can lead to damage, and overheating the windings can cause the insulation to deteriorate, which reduces the life of the transformer.

Basis for Certification

Evaluation Approach

The BIOTEMP® evaluation was designed to provide the data necessary to draw conclusions on the fluid's performance, chemical composition, toxicity, and safety. The evaluation included a review of supporting documents, information, and laboratory data submitted by ABB, and field sampling to provide independent data on the technology's performance, chemical composition, and toxicity.

The field sampling was conducted at ABB's manufacturing facility in South Boston, Virginia and at Pacific Gas and Electric's (PG&E) in-service transformers in San Francisco, California. PG&E is an ABB customer and agreed to provide staff and access to three in-service transformers as part of the field sampling activities. Prior to the field sampling, DTSC prepared a Technology Evaluation Workplan (Workplan) to identify specific field objectives, data quality objectives, testing procedures, and roles and responsibilities. ABB assumed overall responsibility for obtaining access to all locations where field sampling was conducted. DTSC staff provided independent oversight and were present to observe all field sampling activities.

The oldest transformer in-service using BIOTEMP® as the dielectric insulating fluid is 2.5 years old. Since the technology is still new, no data was available to assess the long-term transformer performance and waste characteristics of BIOTEMP® fluid at the end of its service life. Based on historical accelerated life testing results per American National Standards Institute (ANSI)/ Institute of Electrical and Electronic Engineers (IEEE) C57.100-1986, a transformer using BIOTEMP® is estimated to last 20 years which is comparable to a mineral oil-based transformer.

Verification Objectives

The verification/certification objectives were to verify the applicant's technology performance claims listed below.

> **Verification/Certification Claim #1 - General Performance**: In the following composition ratio (98.5% vegetable oil, 1.5% additives), BIOTEMP® meets criteria for oxidative, thermal, and chemical stability, as measured by Oil Qualification Tests - ASTM D3487 (Mineral Oil) and ASTM D5222 (High Temperature Hydrocarbons).

Verification/Certification Claim #2 - Aquatic Biodegradability: BIOTEMP® biodegrades 97% in 21 days, based on the average of several performance tests as measured by the Coordinating European Council (CEC) Test Method CEC-L-33-A-93.

Verification/Certification Claim #3 - Flammability: BIOTEMP® has a Flash Point of at least 300°C, and a minimum Fire Point of 300 °C, based on the average of several performance tests as measured by ASTM D92 (Cleveland Open Cup).

Verification/Certification Claim #4 - Acute Toxicity: The virgin BIOTEMP® product passes the toxicity characteristic criteria in Code of California Regulations, Title 22, Section 66261.24(a)(6) based on U.S. EPA/600/4-90/027F Test for Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms.

Other Verification/Certification Tests: Verify that BIOTEMP® consists of greater than 98.5 % vegetable oil and less than 1.5% antioxidant and color additives; the formulator is meeting selected ABB purchase specifications; establish a baseline for measuring potential metals leaching and oil degradation of BIOTEMP® under electrical loading over time; evaluate the worker health and safety aspects of BIOTEMP®; and estimate costs of using BIOTEMP® as compared to those of mineral oil.

Verification Activities and Results

As part of this verification/certification, DTSC developed a technology evaluation workplan, which described the sample collection procedures and analyses performed. Samples were collected under DTSC oversight to ensure the samples were independent and representative. All samples were assigned a field sample identification number, which was determined prior to sampling. Proper chain of custody and storage procedures were followed. Four different laboratories were used to analyze the collected samples: Doble Engineering for the American Standard Testing Methods (ASTM) methods, Krueger Food Laboratories for the Association of Analytical Chemists (AOAC) methods, DTSC Hazardous Materials Laboratory (HML) for the semi-volatile organic compounds (SVOCs) and metals analyses, Associated Laboratories for the fish bioassay (acute toxicity) tests, and Powertech Laboratories for the aquatic biodegradability tests. Each laboratory sent data and reports directly to DTSC.

Four samples from three different virgin product lots (a total of twelve samples) were collected at ABB's manufacturing facility in South Boston, Virginia. Two lots were contained in 55-gallon drums while the third lot was contained in a 250-gallon tank. Barrel samples were collected using a glass Coliwasa. A new glass Coliwasa was used at each new barrel sampled to reduce the potential of cross contamination between samples. The composite tank samples were collected at a sampling spigot located at the bottom of the tank. Approximately one pint of oil was drained from the tank via the spigot prior to sampling.

Three samples, one from each lot, were analyzed by the following methods: EPA Method 8270/3520 for SVOCs; EPA Method 6010/5030 for metals; U.S. EPA Method 600/4-90/027F for acute toxicity; U.S. EPA Method OPPTS 835.3110 for aquatic biodegradation; AOAC Method 981.11, Oils and Fats; AOAC Method 972.28, Total Fatty Acids in Oils and Fats; AOAC Method 963.22, Methyl Esters of Fatty Acids in Oils and Fats; AOAC Method 983.15, Phenolic Antioxidants in Oils, Fats, and Butter; AOAC Method 977.17, Polymers and

Oxidation Products of Vegetable Oil; ASTM Method D92, flash and fire point; ASTM Method D97, pour point; ASTM Method D445, kinematic viscosity at 0°C, 40°C, and 100°C; ASTM Method D877, dielectric breakdown (minimum); ASTM Method D1816, dielectric breakdown (gap 1.0 mm); ASTM Method D3300, dielectric breakdown (impulse); ASTM Method D924, dissipation factor at 25°C and 100°C; ASTM Method D2440, oxidation stability at 72 and 164 hours; ASTM Method D2112, oxidation stability (rotary bomb); and ASTM Method D1533, water content. One duplicate was analyzed for SVOCs, metals, and the AOAC and ASTM methods listed above. Two matrix spikes and an equipment blank were analyzed for SVOCs and metals. A field blank was analyzed for metals only. Six additional samples were also analyzed using the same ASTM methods except for the kinematic viscosity, which was only measured at 40°C**.**

Virgin product samples collected as part of this verification/certification were from lots produced by ABB's off-site blender. Since BIOTEMP® was blended off-site, ABB was not able to continuously monitor the blending of antioxidants into the oil and make adjustments based on atmospheric conditions such as humidity. Lots blended at ABB's South Boston facility were not available for this sampling event since ABB was completing installation and testing of their on-site blending equipment.

Four different in-service transformers were also sampled as part of this verification/certification: one owned by ABB located in South Boston, Virginia, and three owned by PG&E in San Francisco, California. The sampled transformers were in service for at **least one year** and part of a regular sampling/testing environment. In-service fluid samples were collected by ABB and PG&E representatives under DTSC oversight and in conjunction with PG&E's on-going sampling program. Only one sample per transformer was collected to minimize the amount of fluid removed from each transformer and the impact to the ongoing test program. New Tygon tubing connectors were used at each transformer fluid sampling port to reduce the potential of cross contamination.

The transformer pressure gauge is checked to confirm the unit is under positive pressure prior to sampling. A sampling syringe with Tygon tubing and a T-shaped sampling valve is attached to the sampling port. The T-shaped sampling valve is set to allow oil to flow through a purge line, which bypasses the sampling syringe. The sampling port valve is cracked open and oil is purged through the Tygon tubing, sampling valve, and purge line. After a few pints of oil have been purged through the line, the sample bottles are filled.

The in-service transformer samples were analyzed using the same methods listed for the virgin product samples for SVOCs, metals, and the AOAC analyses. To minimize the amount of fluid removed from each transformer, the in-service transformer samples were only tested by ASTM Method D924 for dissipation factor at 25°C, by ASTM D92 for flash and fire point, by ASTM Method D1533 for water content, and by ASTM Method D4308 for conductivity.

DTSC staff also reviewed internal product development testing data provided by ABB. These data were collected as part of ABB's ongoing internal testing prior to entry into the verification/certification agreement. Historical data collected by independent testing facilities under contract with ABB were also used. These data provided background information on the technology performance for past virgin lots and indicated trends on the fluid's performance in tested transformers for select ASTM parameters.

1. General Performance

BIOTEMP® was tested for select physical, chemical, thermal, and dielectric properties to verify general performance claims listed in ABB's product specifications. Since no standard suite of general performance tests exist for vegetable oil-based dielectric fluids, two ASTM specifications developed for mineral oils (ASTM D3487) and high temperature hydrocarbons (HTH) (ASTM D5222) were used. According to ABB, BIOTEMP® had similar dielectric and oxidation properties to those for mineral oil and HTH fluid. For the in-service transformer samples, results were compared to International Electrochemical Commission (IEC) 1203 specification for in-service synthetic organic esters since BIOTEMP® has similar fluid characteristics when in use. Results for the thermal properties are discussed under the flammability verification claim. Data variability reported for the virgin product results were calculated at a 95% confidence.

Virgin Product Performance Results

Dielectric Properties (or Dielectric Strength)

Dielectric breakdown and dissipation factor are the basic properties used to evaluate a dielectric fluid's performance. The minimum, gap, and impulse dielectric breakdown voltage was determined for BIOTEMP® along with the dissipation factor at 25°C and 100°C.

Dielectric Breakdown

The minimum and gap dielectric breakdown tests measure the minimum voltage required to cause arcing between two submerged electrodes in a dielectric fluid. A low value may indicate the presence of water, dirt, or other electrically conductive particles in the oil, which may cause damage to the transformer core or windings due to arcing. The minimum and gap dielectric breakdown values for the virgin BIOTEMP® samples averaged 50 kilovolt (kV) ± 3 kV, and 37 kV ± 2 kV, respectively. These values were higher than the lowest value specified for the minimum and gap dielectric breakdown voltages for all three specifications.

The impulse dielectric breakdown value is designed to determine the minimum voltage to cause arcing in the fluid under lightning or power surge conditions. Of the ten samples analyzed, six samples had voltages ranging from 214 kV to 226 kV, which were higher than the minimum voltage listed under ASTM D3487 of 145 kV. The other four samples had voltages ranging from 130 kV to 136 kV. All ten samples exceeded the ABB minimum voltage specification of 100 kV. The percent difference between sample results collected from the same barrel and the same lot but analyzed at different points in time was between 48% and 54%. The percent difference for samples from the same barrel, the same lot, and analyzed at the same point in time, was 3%. These large variations in the sample results from the same drum and lot suggest inherent inaccuracies within the method and possible quality issues associated with Doble.

Dissipation Factor

The dissipation factor is used to measure the dielectric losses to an insulating dielectric fluid (such as oil) when it is exposed to an alternating electric field. For ASTM Method D924, the dissipation factor is determined by passing an alternating electric current through a test cell filled with dielectric fluid and measuring the capacitance with an electronic bridge circuit. This value is used to control the product quality, and to determine changes in the fluid due to contamination or degradation during use. A low dissipation factor indicates a low dielectric loss and a low contaminant concentration (e.g., dirt, water, or metals).

The ten sample results had dissipation factors averaging 0.075% ± 0.054% at 25°C, and 1.665% ± 0.762% at 100°C. Four sample results were much higher than the maximum dissipation value of 0.05% at 25°C for ABB and ASTM D3487 specifications, and 2.0% at 100°C for ABB specifications. None of the ten samples were found to meet the ASTM D5222 specification values of 0.01% at 25°C and 0.3% at 100°C, and the ASTM D3487 specification value of 0.3% at 100°C.

Chemical Properties

<u>Oxidation Stability</u>

Oxidation stability was originally designed to assess the amount of sludge and acid products formed in mineral transformer oils under specific test conditions. Good oxidation stability minimizes the formation of sludge and acid in order to maximize the service life of the oil. Oils that meet the requirements specified for ASTM Method D2440 tend to minimize electrical conduction, ensure acceptable heat transfer, and preserve system life. Per ASTM Method D2440, there is no proven correlation between performance in this test and performance in service, since the test does not model the whole insulation system (oil, paper, enamel, wire). However, the test can be used as a control to evaluate oxidation inhibitors and to check the consistency of the oxidation stability of production oils.

The first oxidation stability tests on BIOTEMP® were performed per ASTM Method D2440 over a 72 hour period (the 72 hour test). After 72 hours, the ten sample results averaged 0.02% ± 0.005% for the percentage of sludge generated, and 0.17 milligram of potassium hydroxide per gram (mg KOH/g) ± 0.02 mg KOH/g for the neutralization number. The average percentage of sludge generated met the ABB and D3487 specifications of less than or equal to (≤) 0.2% and ≤ 0.1%, respectively. The average neutralization number met the ABB and D3487 specifications of ≤ 0.2 mg KOH/g and ≤ 0.3 mg KOH/g, respectively.

Oxidation stability tests were also performed on BIOTEMP® per ASTM Method D2440 over a 164 hour period (the 164 hour test). The percentage of sludge generated averaged 0.02% ± 0.01% which met both the ABB and ASTM D3487 specifications of 0.2%. However, the neutralization number averaged 19.02 mg KOH/g ± 1.85 mg KOH/g and exceeded the maximum value for the ABB and ASTM D3487 specifications of 0.5 mg KOH/g and 0.4 mg KOH/g, respectively.

The oxidation stability of BIOTEMP® was also tested using ASTM Method 2112, oxidation stability by rotating bomb (the rotary bomb test). The rotary bomb test was developed as a rapid method for evaluating the consistency of the oxidation stability for a new mineral oil between shipments. Sample results averaged 117 minutes ± 2 minutes, which did not meet the minimum ABB, ASTM D3487 and D5222 specification values of 200 minutes, 195 minutes, and 800-1,000 minutes, respectively.

<u>Water Content</u>

Water content is used by industry to monitor a dielectric fluid's quality. It is an indicator of possible oil deterioration, which could adversely affect the oil's electrical properties such as dielectric breakdown. This value is based on the relative saturation of the water in the dielectric fluid. The relative saturation is based on the amount of water dissolved in the oil divided by the total amount of water the oil could hold at that temperature. The dielectric strength of oil starts to fall when saturation reaches about 50%. For petroleum based dielectric oils, 50% saturation at room temperature is 30-35 milligram per kilogram (mg/kg). Synthetic esters and vegetable oil contain about 500-600 mg/kg of water at room temperature and 50% saturation. Water content at or near 50% saturation may indicate the oil has deteriorated and may cause a lower dielectric breakdown voltage, which can damage the transformer core and windings.

The water content in the ten samples averaged 79 parts per million (ppm) ± 14 ppm and were below the maximum ABB specification value of 150 ppm. The water content was observed to vary between barrels from the same lot, which may be due to variability in the analytical method, atmospheric conditions at the time of testing, and sample storage conditions.

Physical Properties

Pour Point

The pour point indicates the lowest temperature at which oil can be used. The average pour point for BIOTEMP® was -17°C ± 2°C. Initially, four samples were analyzed and the pour point was measured at -21°C. Six additional samples were analyzed at a later date with pour points all measured at -15°C. The difference between the two sets of sample results may be due to a different operator conducting the tests. The pour points for all samples were within the ABB specification range of -15°C to
-25°C.

Viscosity

The dielectric fluid's viscosity is used by transformer designers to confirm that the fluid is appropriate for the unit under certain operating conditions. The viscosity of BIOTEMP® was determined at 0°C, 40°C, and 100°C. The viscosities at 0°C, 40°C, and 100°C varied slightly between samples and averaged 275.77 centistokes (cSt) ± 1.19 cSt, 40.68 cSt ± 0.19 cSt, and 8.59 cSt ± 0.05 cSt, respectively. These values were below the ABB maximum specification values of 300 cSt at 0°C, 45 cSt at 40°C, and 10 cSt at 100°C, respectively.

In-service Transformer Fluid Results

The dissipation factor for all four transformer samples ranged from 0.082 % to 0.252% which were below the IEC 1203 maximum value of 0.8%. One sample had a higher dissipation factor and was observed to have an amber-orange color. This sample was collected from a transformer used by ABB for testing BIOTEMP® under extreme operating conditions such as overload scenarios. Historical results for this transformer showed a steady rise in the dissipation factor corresponding to overload scenarios. A comparison of historical in-service fluid results for the ABB transformer with the ABB virgin product specification shows the dissipation factors differ between 48 to 167% which indicates the oil may have a higher contaminant content due to use. The color and higher dissipation factor for the ABB transformer might indicate thermal decomposition of the fluid or possible oxidation.

The water content for the in-service transformer samples ranged from 15 ppm to 78 ppm, which was below the IEC 1203 and ABB maximum value of 400 ppm and 100 ppm, respectively. Historical water contents for the ABB transformer were below the ABB maximum value for all but one point. When compared to the other transformer results, the higher water content results for INS-07 correspond to overload tests conducted by ABB.

The conductivity values ranged from 8.51 picosiemen per meter (pS/m) to 24.65 pS/m and were greater than the minimum value specified in the original ABB specification of 2.0 pS/m. ABB has since discontinued use of this specification since high conductivity values do not affect the oil's performance. IEC 1203 did not specify a conductivity value. Again, the higher conductivity values for INS-07 corresponds to overload tests and were probably the result of extreme operating conditions.

2. Aquatic Biodegradability

Three virgin BIOTEMP® samples were tested by the Coordinating European Council (CEC) test method CEC-L-33-A-93, which compares the biodegradation potential of BIOTEMP® against the standard oils specified in the test method. The average biodegradability of BIOTEMP® was 99% ± 3% at 95% confidence after 21 days. An earlier study by ABB showed 90% biodegradation after 21 days.

While mineral oil was not tested as part of this study, literature data were available on biodegradability using an older version of the CEC-L-33-A-93, a U.S. EPA method, and an Organization of Economic Cooperation and Development (OECD) method. The Universite de Liege study reported the biodegradability of mineral oil over 70% after 40 days using test method CEC-L-33-T-82. A U.S. Army Corp of Engineers document reported the biodegradation rates for conventional mineral oil ranged from 42-49% after 28 days using U.S. EPA Method 560/6/-82-003, Aerobic Aquatic Biodegradability. Another study by the Conservation of Clean Air and Water-Europe (CONCAWE) reported a ready biodegradation rate for a light naphthenic distillate mineral oil of 28% after 28 days when analyzed by OECD 301B, Sturm test. Both the U.S. EPA and OECD methods estimated the degree of biodegradability by the amount of carbon dioxide (CO_2) produced and expressed this result as a percentage of the theoretical CO_2, which can be produced. These methods are not considered equivalent to CEC-L-33-A-93 but the data does indicate that mineral oil is not readily biodegraded.

Based on these results, the virgin BIOTEMP® fluid appears to biodegrade more readily than mineral oil. Although BIOTEMP® readily biodegrades per this test, releases to water should be prevented. The product's ability to degrade in the environment is dependent on factors such as geography, pH, temperature, oxygen concentration, dispersal of oil, the presence of other chemicals, soil characteristics, nutrient quantities, and populations of various microorganisms at the location.

3. Flammability

The flash and fire point for virgin and in-service BIOTEMP® fluid were determined using ASTM Method D92, Cleveland Open Cup test. The flash point was measured to assess the overall flammability of the fluid and determine the presence of volatile or flammable material at elevated temperatures. The fire point was measured to determine the temperature at which the fluid could support combustion. These values were compared to ABB's specifications for BIOTEMP®. They were also compared to ASTM D3487 for flash point, and ASTM D5222 for fire point, which are designed for virgin mineral oil and HTH oil, respectively. The data variability was calculated at 95% confidence. The virgin product samples had flash and fire points averaging 331°C ± 3°C and 360°C ± 1°C, respectively. The in-service samples had flash and fire points ranging from 328°C to 334°C and 362°C to 364°C, respectively. These values met ABB and ASTM specifications with flash points greater than 300°C and 145°C, and fire points greater than 300°C and within 304 to 310°C, respectively.

The fire point results agreed with those obtained by Underwriters Laboratory (UL) and the Factory Mutual Research Corporation (FMRC) of 354°C and 360°C, respectively. UL determined the flash point at 243°C while FMRC determined a flash point at 330°C. The lower flash point reported by UL was due to their use of a different test method.

UL classified BIOTEMP® as a dielectric medium with a fire hazard rating of 4 to 5 which is less hazardous than paraffin oil. BIOTEMP® is one of five products listed by UL as a Class 4 to 5 dielectric medium.

FMRC classified this product as a less flammable transformer fluid. FMRC also identified BIOTEMP® as an alterative to high fire point hydrocarbons, silicone fluids, and synthetic esters or hydrocarbons where fire resistance, improved high temperature operation, and improved cooling are desired.

4. Acute Toxicity

Three virgin BIOTEMP® samples, one from each lot, were analyzed by U.S. EPA method, *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms*, EPA/600/4-90/027F, August 1993. The tests used juvenile pimephales promelas (fathead minnow) and samples were prepared in accordance with the "Static Acute Bioassay Procedures for Hazardous Waste Samples" developed by the California Department of Fish and Game, Water Pollution Control Laboratory and specified in the Code of California Regulations, Title 22, Section 66261.24(a)(6). This procedure requires using the wrist-action shaker method to dissolve the oil. Dissolved oxygen (DO) content, pH, and temperature were monitored and maintained as required by the method.

The lethal concentrations for 50% of the test population (LC_{50}) values for this evaluation were less than 250 milligram per liter (mg/L). Historical results provided by ABB reported a LC_{50} of 776 mg/L.

A review of both the historical results and the verification/certification results was conducted to identify the differences, which could lead to such conflicting results. The main difference between the two sets of results was the sample preparation method used. Samples with the lower LC_{50} results were prepared using the wrist-action shaker method while samples with the higher LC_{50} results used a carrier solvent to make the oil miscible in water, per U.S. EPA method, *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to*

Freshwater and Marine Organisms. Oil samples prepared using the wrist action method are thought to stratify, with the oil at the top of the tank. Fish swimming through this upper layer of the tank will become coated with the product and gill exchange will be impaired. Oil samples prepared using the wrist shaker method are thought to provide more realistic results for conditions, which may occur during an environmental release. Samples prepared using the carrier solvent provided results that reflect systemic (chemical) impacts on fish. For hazardous waste classification, the end-users should characterize the spent BIOTEMP® at the time of disposal since changes may occur to the oil due to use, storage, or age.

5a. Chemical Composition

The chemical compositions of the virgin and in-service fluids were analyzed for SVOCs and metals to verify chemical composition. These samples were also analyzed by various AOAC methods to create a chemical "fingerprint". Data variability was calculated at 95% confidence

The virgin BIOTEMP® samples averaged 80.06% ± 0.26% oleic acid, 10.45% ± 0.08% diunsaturated fatty acids, 0.26% ± 0.02% triunsaturated fatty acids, and 9.22% ± 0.18% saturated fatty acids. The in-service BIOTEMP® samples had 79.55% to 84.41% oleic acid, 5.38-10.68% diunsaturated fatty acids, 0.21%-0.27% triunsaturated fatty acids, and 9.50-9.99% saturated fatty acids. The average phenolic antioxidant concentration for the virgin product was 3,207 mg/kg ± 103 mg/kg. Phenolic antioxidants ranged between 2,990 and 3,600 mg/kg in the in-service transformer samples. The results for both the virgin and in-service samples were similar to the formulation provided by ABB.

The polymer and oxidation product values determined by AOAC Method 977.17 are simple indicators used in the food industry to assess the quality of vegetable oil after exposure to heat. If lower values are reported for a oil as it is reheated, the difference is assumed to show an increase in non-elution material (compounds not dissolved using a solvent) that indicates the polar compounds in the oil such as unsaturated fatty acids are degrading. Compared to the average virgin product value of 2.23% ± 0.69%, the in-service fluid samples had values ranging from 1.39% to 2.40% and appear to have degraded slightly due to use except for one sample.

For the 65 standard SVOC compounds analyzed by HML, only n-nitrodiphenylamine was detected around the detection limit of 20 mg/L for the virgin and in-service transformer samples. This may be a component of one of the antioxidants used in the fluid. For the in-service fluid, bis-(2-ethylhexyl)phthalate was also detected. This compound, a widely used plasticizer, was also detected in the equipment and field blanks collected. Other tentatively identified compounds were TBHQ, 2-isopropyl-1,4-benzenediol, 2,3-dihydro-2-methyl-5-phenyl-benzofuran, 2-isopropyl-1,4-benzoquinone, p,p'-dioctyldiphenylamine, beta-sitosterol, squalene, and vitamin E.

Metals were not detected in the in-service transformer samples except for INS-2, which had a zinc concentration of 2.3 mg/kg. For the virgin samples, copper and zinc were detected in one sample at 4.13 mg/kg and 2.02 mg/kg, respectively. Barium was detected in one sample at 0.31 mg/kg and two other samples at 0.32 mg/kg.

5b. Worker Health and Safety Aspects

DTSC reviewed material safety data sheets (MSDSs) and information on a transformer unit and its operation to determine potential hazards and regulations associated with BIOTEMP® usage. These hazards were then compared to potential hazards associated with select mineral oil-based and silicone oil-based transformer fluids. The discussion of the potential hazards and regulations below is not considered comprehensive. The end-user is still responsible for identifying potential hazards and implementing applicable regulations associated with worker health and safety.

The BIOTEMP® MSDS lists the components as >98.5% vegetable oil and <1.5% additives (e.g., antioxidants and color). The antioxidants used in this product are not listed as hazardous materials. Two of the antioxidants have been cleared by the Food and Drug Administration (FDA) for use as an indirect food additive in food packaging while the third antioxidant is identified as a food grade antioxidant. Although the BIOTEMP® components may be food grade, this product should not be used as a food product.

According to the BIOTEMP® MSDS, this product is also not considered a hazardous substance as defined under Title 8, California Code of Regulations, Section 5194, Hazard Communications. However, this does not relieve the end-user who uses this product from providing workers with information and training necessary to handle BIOTEMP® safely. Workers should review the MSDS and be familiar with the information concerning first aid procedures, physical properties, personal protective equipment (PPE), respiratory protection, and slip hazards. Workers should wash skin that has contacted the product with soap and water. For eye contact, the eyes should be flushed with water. The primary physical property workers should be aware of is the product's flash point of greater than 300°C. In the case of a BIOTEMP® spills, employees should be aware of the increased slip hazard in the affected area due to the product.

Before working with BIOTEMP®, employees should ensure the work area has adequate ventilation, and the appropriate respiratory protection and protective clothing are selected. When working with hot BIOTEMP®, workers should don neoprene gloves, rubber boots and aprons. Respiratory protection should only be worn if oil mists or dusts contaminated with oil are detected at concentrations equal to or exceeding the permissible exposure limit (PEL). OSHA has set the PEL for vegetable oil mist as a nuisance particulate at 15 milligram per cubic meter (mg/m^3) and 5 mg/m^3 for respiratory protection for an 8-hour time-weighted average (TWA) exposure. In California, the nuisance particulate PEL is 10 mg/m^3. The end-user should consult the appropriate regulatory authority about applicable nuisance particulate PELs used in their area. If the transformer is located in a poorly ventilated area, then workers should use appropriate engineering controls to ventilate the area. Based on the MSDS information on BIOTEMP®'s antioxidants, BIOTEMP® may produce carbon monoxide, carbon dioxide, nitrogen oxides, and other toxic compounds when the antioxidants thermally decompose. Mineral oil-based and silicone oil-based transformer fluids may also thermally decompose and produce fumes, smoke, carbon monoxide, aldehydes and other products. For some mineral oil-based transformer fluids, sulfur oxides are also listed as a possible decomposition product while silicon dioxide is listed for some silicone oil-based fluids. No data are available on the composition of emissions from transformers in general.

When comparing the PPE requirements for handling BIOTEMP® to select mineral oil-based transformer fluids, the requirements were found to be similar. This comparison is based on MSDS information for select mineral-oil-based transformer fluids obtained from the Vermont Safety Information Resources, Inc. (SIRI) MSDS archive. However, respiratory protection for the mineral oil-based transformer fluids is required when the mineral oil mist concentration equals or exceeds the OSHA PEL set at 5 mg/m^3 for an 8-hour TWA exposure. For select silicone oil-based transformer fluids found in the Vermont SIRI MSDS archive, workers are advised to don impervious gloves and chemical goggles when handling the fluid.

Occupational exposure to transformer fluid is limited and associated with infrequent activities such as filling, draining, or sampling of transformers. These activities are not likely to generate a mist or aerosol at concentrations approaching the PEL. Potential hazards associated with filling or draining the transformer include slipping on work surfaces where the product was spilled, or splashing of the material into the eyes or onto the skin. Potential hazards associated with sampling the transformer include coming in contact with extremely hot oil, potential electrical arcing from the transformer, or slipping hazards due to spilled BIOTEMP® on the floor.

MSDS information for three silicone transformer fluids identified as less-flammable transformer oils by UL and FMRC were reviewed along with several mineral oil-based transformer fluids listed in the Vermont SIRI MSDS Archive. Health and safety information on the components listed on the MSDSs were compared to information listed in 2000 edition of Sax's Dangerous Properties of Industrial Materials. The primary component of the mineral oil-based transformer fluid was a hydrotreated light naphthenic petroleum distillate (Chemical Abstract Service [CAS] No. 64742-53-6) ranging from 30-100%, which was identified as an International Agency for Research on Cancer (IARC) confirmed carcinogen, based on experimental data for animals. The primary ingredient of the silicone oil-based transformer fluids was dimethyl polysiloxane (CAS No. 63148-62-9) listed at 100% and identified as a combustible liquid, a teratogen, and the cause of reproductive effects based on experimental data on animals.

5c. Estimated Cost of BIOTEMP® versus Mineral Oil

The initial purchase cost of a new transformer unit containing BIOTEMP® is approximately 1.25-1.30 times more than the cost for a comparable mineral oil transformer. The price of the BIOTEMP® fluid ranges from $7 to $11 per gallon depending on the volume purchased and is based on estimates provided by ABB. The fluid is available in 5-gallon containers, 55-gallon drums, 200-gallon totes, 6,000-gallon tanker trucks, or by the rail car. Prices for mineral oil typically range from $2 to $3 per gallon. Monitoring costs will vary depending on the maintenance program the purchaser has in place. The waste characterization cost for a transformer using BIOTEMP® or mineral oil are anticipated to be approximately the same except for mineral oil suspected to contain PCBs where the costs will be higher. The disposal cost for mineral oil and BIOTEMP® are assumed to be comparable since data are not available on the waste characteristics of BIOTEMP® after 25 years of use.

For a retrofilled transformer, no additional costs due to modifications of the transformer unit are incurred for using BIOTEMP®. The costs associated with draining and disposing of the used oil are expected to be the same for both mineral oil and BIOTEMP®. Costs associated with flushing and filling a retrofilled transformer with BIOTEMP® versus mineral oil are also anticipated to be higher since BIOTEMP® costs between $4 to $9 per gallon more than mineral oil depending on the volume purchased.

Certification Statement

Under the authority of Health and Safety Code section 25200.1.5, the BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid (BIOTEMP®) is hereby certified as a pollution prevention technology subject to the specific conditions including the limitations/disclaimer set forth in the Certification Notice as published in the California Regulatory Notice Register on July 12, 2002, Register No. 2002, Volume No. 28-Z, pages 1443-1452. Field test results show that the ABB Inc. BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid is a biodegradable, vegetable oil-based dielectric fluid with a flash and fire point above 300°C. The product has dielectric breakdown voltages comparable to mineral oil and high temperature hydrocarbon oil. The product may have varying amounts of antioxidants based on past and current oxidation stability results. BIOTEMP® samples from normal in-service transformers had flash and fire points above 300°C, and showed no signs of oil degradation due to use. Spent BIOTEMP® fluid may exhibit a hazardous characteristic per California's hazardous waste characteristic definition based on limited data for the virgin product. The end-user must characterize the spent BIOTEMP® at the time of disposal since changes may occur to the oil due to use, storage, or age.

Limitations of Certification

DTSC makes no express or implied warranties as to the performance of the BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid. Nor does DTSC warrant that the BIOTEMP® product is free from any defects in workmanship or materials caused by negligence, misuse, accident or other causes. However, DTSC believes that the BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid can be used in accordance with the conditions specified in this certification notice to achieve the results specified herein.

Use of the certified technology is limited to transformers as an insulating dielectric fluid. The product must also meet the requirements specified by Underwriters Laboratories (UL) and the Factory Mutual Research Center (FMRC) for a less flammable transformer fluid and transformer installation requirements specified under the National Electrical Code (NEC).

Specific Conditions

1. Applicability. This certification is limited to the use of BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid (BIOTEMP®) as an insulating dielectric fluid in transformers up to 20 megavolt amperes (MVA).

2. Use for Transformers. This certification is limited to use of the BIOTEMP® in transformers up to 20 megavolt amperes (MVA). Use of BIOTEMP® does not automatically classify the transformers as less flammable per the Factory Mutual Research Center definition. The user is responsible for assessing whether existing transformers where BIOTEMP® will be substituted for the original dielectric fluid (retrofilling) meets current NEC requirements.

3. Compliance with the Oil Spill Pollution Prevention and Management Requirements. Use of the BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid must be in compliance with all federal, state, and local regulations requiring the reporting of oil releases to the soil or water and their subsequent clean-up.

4. Compliance with Hazardous Waste Classification and Disposal Requirements. Prior to disposal, spent BIOTEMP® and waste material generated from the clean-up of BIOTEMP® spills must be characterized per 22CCR Section 66261.20 and managed accordingly. Spent BIOTEMP® or waste material from spills shall be tested for polychlorinated biphenyls (PCBs) if the transformer in question formerly contained a PCB-laden oil. The disposal of virgin and spent BIOTEMP® must be in compliance with all federal, state, and local regulations.

5. Compliance with Used Oil Management Requirements. The user shall be responsible for determining if the spent BIOTEMP® meets the definition of an used oil per 22CCR Section 66279.1(d), contains no more than 5 ppm of PCBs, and has a total halogen content of less than 1,000 ppm. If the spent BIOTEMP® meets these criteria, then it must be managed as an used oil under California's Used Oil Management Program and sent to a certified California waste oil recycler. If the spent BIOTEMP® does not meet the definition of an used oil per 22CCR Section 66279.1(d) but does meet the definition of a hazardous waste per 22CCR Section 66261.20, then it must be managed as a hazardous waste.

6. Compliance with Worker Health and Safety Laws. Use of BIOTEMP® in transformers must be in compliance with all federal, state and local regulations relating to the protection of worker health and safety. In California these include, but are not limited to, Cal-OSHA and OSHA requirements.

7. Personnel Training. Operators with knowledge and proper training in transformer sampling are required to collect samples from in-service transformers. Training includes, but is not limited to, safe operation and maintenance of the transformers, and knowledge of safe work practices and operating procedures for high voltage electrical equipment.

8. Compliance with Applicable Federal, State, Local Regulations. The user shall comply with all applicable federal, state, and local regulatory requirements.

9. Modifications and Amendments at the Request of the Applicant. Modifications and amendments to this certification may be requested by the applicant and shall be subject to approval by DTSC.

10. Certification Reference. The holder of a valid hazardous waste environmental technology certification is authorized to use the certification seal (California Registered Service Mark Number 046720) and shall cite the certification number and date of issuance in conjunction with the certification seal whenever it is used. When providing information on the certification to the user of the technology or another interested party, the holder of a hazardous waste environmental technology certification shall at a

minimum provide the full text of the final certification decision as published in the California Regulatory Notice Register.

11. The user of the certified technology shall maintain adequate records to document compliance with the conditions of certification. The records shall be maintained onsite and available for inspection.

Regulatory Implications

This certification is for the specific claims, conditions, and limitations outlined in this notice, and is based on DTSC's evaluation of the technology's performance. The Certification does not change the regulatory status of BIOTEMP® Vegetable Oil-Based Insulating Dielectric Fluid; it should, however, facilitate and encourage the acceptance of this technology as a pollution prevention alternative to transformer oils containing PCBs, mineral oils, and silicone oils.

Use of this technology, as a pollution prevention alternative does not require a hazardous waste management permit issued by DTSC. However use of the technology may be subject to regulation by other state and local agencies. For each specific application, the end-user must ensure compliance with all applicable regulations and standards established by other state and local agencies.

This Certification is issued under the California Environmental Technology Certification Program, and is therefore subject to the conditions set out in the regulations, such as the duration of the Certification, the continued monitoring and oversight requirements, and the procedures for certification amendments, including decertification.

By accepting this Certification, the manufacturer assumes, for the duration of the Certification, responsibility for maintaining the quality of the manufactured materials and equipment at a level equal or better than was provided to obtain this Certification and agrees to be subject to quality monitoring by DTSC as required by the law, under which this Certification is granted.

Duration of Certification

This certification will remain in effect for three years from the date of issuance, unless it is amended or revoked for cause.